Continental-Margin Processes Recorded in Shelf and Canyon Sediments
Sediment Deposition, Erosion and Accumulation on a Tidal Flat Adjacent to a River Mouth

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LONG-TERM GOALS

The ultimate goal of the work in the Gulf of Lions is to understand the relationships between sediment transport and accumulation in shelf and slope environments, and how they lead to the formation and preservation of sedimentary strata in the seabed.

The goal of the tidal-flats project during the first year was to help plan a DRI study of Korean and US intertidal sedimentation.

OBJECTIVES

The objectives of research during FY07 were to:

1) complete lab analyses and write papers about: Rhone flood deposits, the Gulf of Lions mid-shelf mud deposit, off-shelf transport, and submarine-canyon sedimentation;

2) publish the STRATAFORM Master Volume (results are summarized under Work Completed); and

3) help with planning the Tidal Flats DRI (results are summarized under Work Completed).

APPROACH

During 2004-2005, a study was initiated in the Gulf of Lions, with examination of sediment discharge from the Rhone River, dispersal across the continental shelf, and transport into and through two submarine canyons (Cap Creus and Lacaze-Duthiers). Cores have been examined by several radioisotopes to document rates of deposition, biological mixing, and net accumulation. In addition, the character of the sediment was documented by x-radiography and grain-size analysis. These studies of sedimentation are being directly compared to dynamical observations of sediment transport by other investigators.

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WORK COMPLETED

Laboratory work was continued and written publications were initiated for studies in the Gulf of Lions, as described in the next section.

The integrated synthesis of STRATAFORM final results was published by Blackwell, and is listed in Publications

Several efforts were completed for the Tidal Flats DRI, including: interacting with other scientists to help design the project at a workshop in Honolulu, writing a portion of the Science Plan (White Paper), negotiating with Korean scientists about a modified study in Korea, and helping to identify and explore US tidal flats for investigation (Skagit and Willapa flats).

RESULTS

The following are the results of analyses on sediment cores from the Gulf of Lions. A paper presenting the results of work on the Rhône delta is in press, and papers for the other three segments of work are in preparation.

1) RHONE DELTA – Episodic flood delivery provides the bulk of the solid discharge for many small to moderate river systems, including the Rhône River in the northwestern Mediterranean. Several recent studies have demonstrated that the fate of this sediment depends on the coherence between river discharge and energetic ocean conditions. The deposition of flood sediment in the ocean can be confirmed by common signatures of episodic discharge events: presence of ^{7}Be, physical stratification, and elevated clay content associated with low ^{210}Pb activities.

Previous research has indicated that the Rhône River discharge is episodic and generally independent of oceanic conditions. Sometimes the floods coincide with energetic storms and winds from the southeast, which facilitate the movement of sediment towards the southwestern Gulf of Lions. High-resolution coring near the mouth of the Rhône River provides a detailed record of sedimentation associated with past flood events. Cores were collected on two cruises, October 2004 and April 2005, in a study area seaward of the Rhône subaerial delta. Episodic sediment discharge from the Rhône River routinely deposits on the seabed in water depths shallower than 40 m. This is documented by the presence of ^{7}Be in the surficial sediments of physically stratified cores. Through identification of a dilution signature in ^{210}Pb profiles (i.e., increased clay content, decreased ^{210}Pb activity), past flood events are recognized. Greater water depths and distances from the river mouth allow bioturbation to erase these signatures, except in the most extreme events where physical stratification is preserved. Excess ^{210}Pb and ^{137}Cs were ubiquitous in cores from this study, indicating apparent accumulation rates in the range of 2.5 to >10 cm/y. This study confirms that although flood-event signatures provide a basis with which to examine recent flood deposits of all scales, only the thickest deposits are likely to be preserved over the long term (>100 y).

2) MID SHELF MUD DEPOSIT – Sediment is transported southwestward (i.e., in a counter-clockwise manner around the Gulf of Lions) along the middle shelf (~50-80 m water depth). The accumulation rates abruptly decrease to values <1 cm/y; note that the rates just west of the river mouth are 7 mm/y. Strong currents associated with wind events transport sediment, forming a mud belt in ~60-80 m water depth. Cores show that this deposit regularly decreases in width towards the southwestern gulf, and is characterized by progressive sorting with the absence of sand. The mid-shelf mud deposit is presumed

to be the dominant path of sediment dispersal, because much modern sediment is sequestered in this deposit and because it connects with the two submarine canyons receiving the greatest sediment flux (Cap de Creus, Lacaze-Duthiers). The mid-shelf deposit contains homogeneous mud accumulating at rates of 2-3 mm/y. We are in the process of establishing a sediment budget for the Gulf of Lions, and expect to document that ~90% of fluvial sediment supply to the Gulf of Lions is accumulating on the continental shelf.

3) OUTER SHELF BYPASS – Previous work in the Gulf of Lions has suggested that sediment may be escaping from the shelf in the western part of the margin, even though this area is distal to the primary sediment source of the region (Rhone River, ~160 km to the NE). Multiple canyons incise the shelf break; however, it is hypothesized that the westernmost canyon, Cap de Creus, is an outlet for much of the Gulf of Lions' sediment. The goal of this work is to quantify the shelf-slope link near Cap de Creus Canyon, by locating zones of accumulation and bypassing on the outer shelf and in canyon heads, and using these seabed data to infer transport pathways. Box cores were collected within the canyon and on the adjacent shelf (in Nov 2003, Mar 2004, Oct 2004, Feb 2005, and Apr 2005). Accumulation rates are spatially variable on the outer shelf (0.5-3.5 mm/yr), and are separated by a zone of bypassing from the canyon heads. Surficial grain sizes show a sharp transition from mud-dominated at mid-shelf depths to sand-dominated near the canyon heads. The shelf south of the canyon also shows coarse-grained characteristics (sand to gravel). These data suggest that strong currents due to veering around headlands are hindering sediment accumulation near Cap de Creus, moving fine-grained material past the outer shelf near the canyon head, and scouring the seabed south of the canyon.

4) SUBMARINE CANYONS – Sedimentation in the canyon also is spatially variable. A sharp transition in surficial grain size is observed in the main thalweg, with sandy deposits unconformably overlying consolidated mud in the upper canyon (<300 m), and unconsolidated muddy deposits unconformably overlying sand in the mid canyon (300-700 m). Fine-grained sediment appears to be preferentially accumulating in mid-canyon thalwegs relative to flanks. Accumulation rates are asymmetric across the canyon, showing higher accumulation rates on the northern flank compared to the southern. Grain-size characteristics also are asymmetric, with finer grain sizes observed on northern flanks compared to southern. These data suggest that (1) sediment is preferentially supplied to the canyon from the shelf/slope adjacent to northern flanks via nepheloid transport from the regional current and/or (2) strong currents are scouring fines from the southern flanks due to enhanced currents veering around Cap de Creus headland. Times-series data on sediment transport rates within the canyon (5 m above bed) suggest both processes may be operating. The furrowed seabed on the southern flank is another indication that strong near-bottom flows may be preferentially sweeping this area. Processes operating within the thalwegs are less obvious. Unconformable sand and mud layers suggest that the upper and mid canyon may be periodically flushed of sediment, which is then transported to deeper parts of the canyon. Gravity-driven flows, possibly associated with strong episodic down-canyon currents due to cold-water cascading, may have produced the observed deposits.

IMPACT/APPLICATIONS

The research completed in this project leads to an improved understanding of the processes that control the geometry of sedimentary deposits over multiple time scales. Especially important is documentation for the distribution of the Rhone flood deposit, and evaluation of the seabed impact of cold-water currents cascading down the submarine canyons.

TRANSITIONS

Other EuroSTRATAFORM investigators are using results from this effort. Those studying the seabed incorporate radiochemical and textural data to document seabed characteristics more fully. Researchers analyzing boundary-layer processes also utilize these data to describe instrumentation sites. Accumulation rates, sediment budgets, and grain-size data are key components to the input parameters of numerical models.

RELATED PROJECTS

Related projects include studies of: the seabed by R. Wheatcroft and P. Wiberg; boundary-layer process by A. Ogston and P. Puig; suspended-sediment dynamics by G. Kineke, P. Hill and T. Milligan; modeling by L. Pratson and J. Syvitski; and organic-carbon studies by S. Miserocchi, L. Langone, and D. Orange.

PUBLICATIONS

Earlier work from this grant that was published in 2007

C.A. Nittrouer, J.A. Austin, M.E. Field, J.H. Kravitz, J.P.M. Syvitski and P.L. Wiberg (eds.), Continental Margin Sedimentation: From Sediment Transport to Sequence Stratigraphy, IAS Spec. Pub. 37, Blackwell Publishing, Oxford, 549 pp. (2007).

C.A. Nittrouer, J.A. Austin, M.E. Field, J.H. Kravitz, J.P.M. Syvitski and P.L. Wiberg, Writing a Rosetta stone: insights into continental-margin sedimentary processes and strata, *in* C.A. Nittrouer et al. (eds.*) Continental Margin Sedimentation: From Sediment Transport to Sequence Stratigraphy*, IAS Spec. Pub. 37, Blackwell Publishing, Oxford, 1-48 (2007).

C.K. Sommerfield, A.S. Ogston, B.L. Mullenbach, D.E. Drake, C.R. Alexander, C.A. Nittrouer, J.C. Borgeld, R.A. Wheatcroft and E.L. Leithold, Oceanic dispersal and accumulation of river sediment, *in* C.A. Nittrouer et al. (eds.*) Continental Margin Sedimentation: From Sediment Transport to Sequence Stratigraphy*, IAS Spec. Pub. 37, Blackwell Publishing, Oxford, 157-212 (2007).

L.F. Pratson, C.A. Nittrouer, P.L.Wiberg, M.S. Steckler, J.B. Swenson, D.A. Cacchione, J.A. Karson, A.B. Murray, M. Wolinsky, T. Gerber, B.L. Mullenbach, G.A. Spinelli, C.S. Fulthorpe, D.B. O'Grady, G. Parker, N.W. Driscoll, R.L. Burger, C. Paola, D.L. Orange, M.E. Field, C.T. Friedrichs, and J.J. Fedele, Seascape evolution on clastic continental shelves and slopes, *in* C.A. Nittrouer et al. (eds.) *Continental Margin Sedimentation: From Sediment Transport to Sequence Stratigraphy*, IAS Spec. Pub. 37, Blackwell Publishing, Oxford, 339-380 (2007).

C.M. Palinkas and C.A. Nittrouer, Modern sediment accumulation on the Po shelf, Adriatic Sea, *Cont. Shelf Res., 27*, 489-505 (2007).

A. García-García, D.L. Orange, S. Miserocchi, A. Correggiari, L. Langone, T.D. Lorenson, F. Trincardi, and C.A. Nittrouer, What controls shallow gas in Western Adriatic Sea? *Cont. Shelf Res., 27*, 359-374 (2007).

Gulf of Lions publications

T.M. Drexler and C.A. Nittrouer, Stratigraphic signatures due to flood deposition near the Rhone River, Gulf of Lions, Northwest Mediterranean Sea, *Cont. Shelf Res.*, (in press).

A. DeGeest, B.L. Mullenbach, P. Puig, C.A. Nittrouer, T.M Lomnicky, D.L. Orange, X. Durrieu de Madron, Sediment accumulation in the western Gulf of Lions, France: the role of Cap de Creus Canyon in linking shelf and slope sediment dispersal systems, *Cont. Shelf Res.*, (in press)

D. Orange, A. García-García, M. Levey, M. Todd, S. Berne, X. Durrieu de Madron, C. Estournel, P. Puig, T. Schoolmeester, M. Canals, J. Fabres, A. Palanques, T. Lorenson, A. DeGeest, B. Mullenbach, T. Drexler, C. Nittrouer, J. Locat, M. Sansoucy, H. Lee, The Cap de Creus canyon head, Gulf of Lions: Active processes revealed by high-resolution mapping, sub-bottom profiles, cores, and moored instruments, *Mar. Geol.*, (in press).

A. Garcia-Garcia, D. Orange, T. Lorenson, O. Radakovitch, T. Tesi, S. Miserocchi, S. Berne, P.L. Friend, C. Nittrouer and A. Normand, Shallow gas off the Rhone prodelta, Gulf of Lions, *Mar. Geol., 234*, 215-231 (2006).

C. Nittrouer, J. Syvitski, P. Weaver, F. Trincardi, S. Berne, M. Canals, Recent advances in knowledge about strata formation on continental margins in North America and Europe, IAS, International Sedimentological Congress, Fukuoka (2006).

T.M. Drexler, C.A. Nittrouer, A.S. Ogston, P. Puig, Sediment record on the Rhone prodelta and processes controlling redistribution along the shelf in the Gulf of Lions, AGU, Fall Meeting, San Francisco (2006).

T. Drexler, C. Nittrouer, A. Ogston, P. Puig, B. Mullenbach, A. DeGeest, Sediment dispersal in the Gulf of Lions: The journey from the Rhone River through submarine canyons in the southwest gulf, AGU-ASLO Ocean Sciences Meeting, Honolulu (2006).

C. Nittrouer, T. Drexler, B. Mullenbach, J. Walsh, P. Puig, A. Ogston, J. Parsons, G. Kineke, S. Kuehl, The importance of modern submarine canyons as sediment conduits on tectonically active continental margins, AGU-ASLO Ocean Sciences Meeting, Honolulu (2006).

B.L. Mullenbach, P. Puig, A.L. DeGeest, D.L. Orange, C.A. Nittrouer, T.M. Drexler, Cap de Creus canyon: a link between shelf and slope sediment-dispersal systems in the Gulf of Lions, NW Mediterranean, AGU-ASLO Ocean Sciences Meeting, Honolulu (2006).